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A large amount of idle capacity under rapid expansion: Policy analysis on the dilemma of wind power utilization in China

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ABSTRACT

Wind power installation in China has increased rapidly since 2004. However, wind power usage remains relatively low resulting in a lot of idle capacity beginning in 2007. In this paper, we determine the main framework of China's current wind power policies and illustrate how these policies led to the rapid installation expansion accompanied by large idle capacity. Building on this, we explore how to alleviate the high installation low wind power usage conflict in China. We establish optimal models to (i) analyze wind power and power grid company behavior; (ii) demonstrate the impact of China's current policies on power and grid companies; and (iii) clarify the causes and mechanisms resulting in high growth and low wind power capacity usage. Our analysis shows that the incentive incompatibility of current policies, which enticed power companies to pursue installation expansion regardless of quality while inhibiting grid companies from improving connectivity, transmission and scheduling technology, is the primary cause for such large-scale idle capacity. The results of our study suggest that the fundamental way to scale up wind power utilization is to enhance policy incentive compatibility, which mainly includes (i) distributing revenues and diversifying risk fairly between power and grid companies; and (ii) motivating power companies to address demand fluctuation actively.

Contents

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1. Introduction

China has long relied on coal-fired power, which has not only consumed a lot of coal, but caused serious environmental pollution [1]. Thermal power accounts for very high proportion of China's total power generation (see Table 1) and creates severe environmental damage. As a renewable, inexhaustible clean energy, wind power plays a significant role in reducing carbon emissions, which is beneficial not only for reducing pollution, but also for improving global environmental quality [2]. In recent years, China has taken positive and supportive measures to promote wind power development. Statistics show that China's cumulative wind power capacity has increased quickly since 2004 [3]. By the end of 2008, China ranked fourth in the world in total capacity, second by 2009, and first since 2010 (see Table 2). This convincingly reveals that China's policy promoting wind power development had a significant impact. But China's wind power development has exposed a serious problem – actual grid access is far less than installed capacity. According to statistics, about 1/3 of the capacity generated by newly installed turbines has failed grid connection since 2008 (see Table 3). This implies that considerable Chinese wind power resources and facilities are idle. This damages not only wind power industry development, but also creates large social welfare losses. According to a survey of the Chinese Wind Energy Association (CWEA), approximately 164 TWh of electric energy is lost due to grid integration failure with turbines. This is equivalent to 5,410,000 t of standard coal [4]. In addition, wind power currently accounts for a fairly low proportion of China's total electricity supply. Therefore, scaling up its utilization is an urgent task for the country [5–7].

Numerous studies on how to reduce wind power's idle capacity in China have found a variety of things hindering its utilization. Those rich wind resource locations are far from electricity demand centers which is generally considered a basic barrier to large-scale wind power connection, because it makes transmission difficult [8,9,12,13]. For example, [8,9] stated that the geographical discrepancy between wind resources and electricity demand makes transmission crucial to wind power development. The statistics confirmed this situation [10]. Many studies pointed out that wind power's inconsistency damages system security and results in large curtailment of wind power establishment [7,8,11,20,31].

Table 1
The role of thermal power in total electricity consumption in China.
Data Source: Yearbook of China Electric Power.

Year	Thermal power (TWh)	Total electric consumption (TWh)	Thermal power as a percentage of total electricity consumption (%)
2004	18103.80	21943.52	82.50
2005	20179.73	24747.41	81.54
2006	23742.00	28499.00	83.30
2007	27207.00	32644.00	83.34
2008	28030.00	34510.13	81.22
2009	30116.87	36811.86	81.81
2010	34166.00	42278.00	80.81
2011	38137.51	46037.00	82.84

Table 2
Top five countries accumulative installation capacity (Million Watt).
Data Source: Global Wind Energy Council.

Country	2011	2010	2009	2008	2007	2006	2005	2004
China	62364	44733	25815	12020	5912	2599	1272	764
USA	46919	40298	35086	25237	16824	11575	9149	6726
Germany	29060	27191	25777	22247	22247	20622	18415	16629
Spain	21647	20623	19160	16689	15145	11623	10027	8263
India	16084	13065	10926	9655	7845	6270	4430	3000

Table 3
China's installed capacity and the generation situations.
Data source: Chinese Wind Energy Committee; Yearbook of China Electric Power; Compilation of Statistics of the Electric Power Industry; China's White Paper on Energy Policy (2012); The Research Report on China's Wind Power Development; International Energy Network: www.Internationalenergy.com; China Renewable Energy Association.

Year	New capacity (MW)	Cumulatives (MW)	Output (TWh)	Percentage of total electricity (%)	Idles (MW)	Percentage of idles as new capacity (%)
2004	196.8	742.6	–	–	–	–
2005	506.9	1249.5	16.40	0.07	–	–
2006	1287.6	2537.1	28.40	0.10	–	–
2007	3311.2	5848.4	57.10	0.17	–	–
2008	6153.7	12002.1	130.79	0.38	2030.8	33
2009	13803.2	25805.3	276.15	0.75	4601.0	33
2010	18928	44733.2	494.00	1.17	5876.4	30
2011	17630.9	62364.2	700.00	1.49	4936.7	28

– denotes that data was not available.

Table 4
Wind power percentage as part of total electricity consumption in the top five countries relative to overall capacity.
Data Source: Central Electricity Authority of India; UN statistical databases; Global Wind Energy Council.

	2011 (%)	2010 (%)	2009 (%)	2008 (%)	2007 (%)	2006 (%)	2005 (%)	2004 (%)
China	1.49	1.17	0.75	0.38	0.17	0.10	0.07	–
USA	2.92	2.00	1.77	1.28	0.80	0.62	0.42	0.34
Germany	7.80	6.20	6.52	6.37	6.23	4.82	4.39	4.15
Spain	15.70	16.60	12.85	10.50	9.04	7.78	7.20	5.61
India	5.52	4.87	4.63	3.76	3.49	1.47	–	–

– denotes that data was not available.

Ensuring stable, reliable and economic power system operation under massive wind power integration is a big challenge for power system operators [8,33]. A number of researchers indicated that wind farms hardly respond to changes in electricity demand having an almost reverse peaking, which leads to reduced wind power consumption [8,17,20].

Most studies argued that China should adjust its policy to remove these barriers. Many researchers recommended that China should improve its wind power pricing system. However, other studies disagree with this recommendation. [15]. Therefore, a comprehensive study is needed urgently to alleviate incompatibility among the countermeasures on how to promote effective wind power utilization [16,18].

Our paper explores an incentive approach to promote compatibility between China's wind power development and utilization. We established analytical models to (i) analyze wind power and power grid company behavior; (ii) demonstrate the impact of China's current policies on power and grid companies; and (iii) clarify the causes and mechanisms resulting in high growth and low wind power capacity usage.

2. Analysis on the current policies

The Chinese government has formulated and issued many policies and measures for promoting wind power development since 2005, such as *People's Republic of China Renewable Energy Law (REL)* in 2006, *Medium and Long-term Renewable Energy*

Table 5
Evolution of wind power tariff policy in China.
Source: NDRC; The National Energy Administration; China–Denmark Wind Energy Development Project Office and Chinese Renewable Energy Industries Association; China Electric Power Yearbook (since 1994); [24,25].

Period	Pricing formulation	Operational procedure
1986–1993	Referring to thermal electricity price	Bargaining between wind farms and users
1994–1997	Generation cost + repayment of capital with interest + reasonable profit	Negotiating and contracting between wind farms and grid companies based on the policy
1998–2002	Tariff approved by price authorities based on examination	Wind farms and grid companies signed agreements according to the tariff approved by price authorities
2003–2005	Tender tariff for national wind power projects; approval tariff for provincial or lower-class wind power projects	Central authority organized bidding for big projects; provincial or local authority examined and approved provincial or local projects
2006–2008	Tender tariff approved by central government for local projects; tender tariff for national projects	Central authority approved the tender tariff according to the sum of cost and revenue of the project investment
Since 2009	Benchmark price determined by NDRC; country was divided into four wind resource areas with four benchmark prices	Wind farms sign with grid companies and submit to national price authority for record

Table 6
Benchmark prices of different resource areas.
Data Source: NDRC.

Types of resource areas	The basis for dividing	Benchmark price (RMB Yuan/kWh)	Benchmark price[a] (USD/kWh)
First-class resource areas	with the richest wind resources	0.51	0.075
Second-class resource areas	with relatively rich wind resources	0.54	0.079
Third-class resource areas	with the modest wind resources	0.58	0.085
Forth-class resource areas	with relatively low wind resources	0.61	0.089

[a] Calculated by the average exchange rate in August, 2009 when the benchmark policy was issued by NDRC.

Development Plan (ML-REDP) published by National Development and Reform Commission (NDRC) in September 2007, and *Eleventh Five-Year Plan on Renewable Energy Development* issued by NDRC in March 2008, etc. These policies clearly show that the basic goals of China's renewable energy policies are to increase its energy supply, optimize its energy structure,[1] ensure energy security, and protect the environment [21–23]. Since *REL* published, the Chinese government has enacted supportive and preferential policies for wind power exploitation in many aspects, such as price protection, priority in grid integration and scheduling, tax breaks and financial support, etc.

2.1. Price protection

Tracing wind power pricing in China, 6 distinct periods exist (see Table 5): (i) based on the benchmark price of coal-fired electric power 1986–1993; (ii) determined by project cost, which consists of investment and corresponding interest 1994–1997; (iii) approved by authorities, based on examination 1998–2002; (iv) validated by bid price or alternatively by authorized price 2003–2005; (v) appraised and fixed according to the sum of cost and revenue 2006–2008; and (vi) ruled by the benchmark price of the local wind energy resource area, since 2009. Although these rules fall within different periods, they are consistent with the goal of protecting wind power development. The main difference among them is the degree of protection on wind power's price. The policy of benchmark price based on resource dominates at present, which went into effect on August 1, 2009 when NDRC issued *The Notice on Improving Wind power Feed-in Tariff Policy*. Its main idea is to divide the country into four wind energy areas and regulate the benchmark price correspondingly as 0.51 Yuan, 0.54 Yuan, 0.58 Yuan and 0.61 Yuan RMB [26]. Table 6 shows benchmark price details. The component of wind power benchmark price under local de-sulfurized coal-fired electricity price is paid by local provincial power grid companies. The one above de-sulfurized coal-fired electricity price is covered by a surcharge on renewable energy electricity tariff across the nation, which is imposed on final users. Therefore, a wind power company has right to sell its full electric power at the wind energy resource area benchmark price where it is located. The price is fixed and consists of two parts – the de-sulfurized coal-fired electric energy price, which is fixed, and the difference between the local wind power benchmark price and that of de-sulfurized coal-fired electric power, which is also fixed. As a result, the feed-in tariff price at which wind power access to network is fixed, i.e.

$$p_{g,i} = p_{s,i} = p_{d,i} + F_A \tag{1}$$

where$p_{g,i}$ is the actual price of wind power access to network, $p_{s,i}$ is local wind power benchmark price,$p_{d,i}$ is the benchmark price of de-sulfurized coal-fired electric power, and F_A is the surcharge of renewable energy electricity tariff.

Correspondingly, the price by which grid companies buy wind power is fixed, i.e.,

$$p_{p,i} = p_{d,i} \tag{2}$$

Note that the benchmark prices determine the actual feed-in tariff of wind power. However, the feed-in tariff is paid only if turbines output online. If turbine-to-grid connections fail, the feed-in tariff is invalid. That is to say, feed-in tariff payment depends on whether electricity is supplied to the grid.

[1] Energy structure usually refers to the proportion of each type of energy as total energy consumption/production and their mutual ratio, for example, the percentage of wind power as total electricity consumption in China in 2011 is 1.49% (Table 4) and that of thermal power is 82.84% (Table 1). The optimization of energy structure is defined as the increase of proportion of clean renewable as total energy consumption/production.

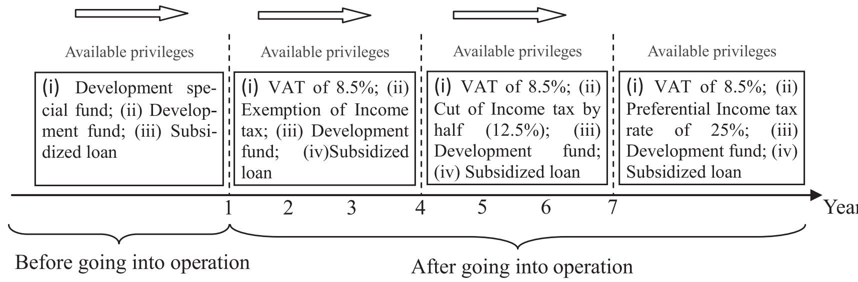

Fig. 1. Flow chart of preferential policies for wind power development.
Source: Renewable Energy Law; Amendment on Renewable Energy Law.

2.2. Favored rules on integrating to the network and scheduling

When *Regulatory Act on Requiring Grid Enterprises Totally Purchase Electricity Based on Renewable Energy*, published by State Electricity Regulatory Commission (SERC) in July 2007, went into effect in September 2007, grid companies were required to purchase full electric energy generated by wind farms. At the same time, wind farms have preferential scheduling rights, and do not participate in online auction [27]. Therefore, if available in terms of technology, the full generation of the wind companies could access the network. Combined with fixed network prices, wind power companies can generate a very stable income.

2.3. Tax breaks and financial supports

REL stipulates that the Ministry of Finance (MF) set up a special fund to support renewable energy development and provide preferential loans with fiscal interest subsidies to qualified renewable energy projects. This law also entrusts tax breaks to wind energy projects, which include income tax reductions from 33% to 25% on the overall level with exemption during first three years and a 50% reduction during second three years (named "three-year exemption and three-year reduction" for short), and value-added tax (VAT) is reduced from 17% to 8.5%. *Amendment on Renewable Energy Law*, implemented on April 1, 2010, further provides that MF establishes a renewable energy development fund to support renewable energy construction [28]. With tax breaks and financial supports, wind power company profit margins expand further. The preferential measures on tax and finance and their application are displayed in Fig. 1.

The intent of these policies was to stimulate wind power investment growth and their effect is very evident. Table 3 shows that newly installed capacity grew by average annual speed of 90.06% ($=[17630.9/196.8]^{1/7}-1$) from 2004 to 2011. Since 2009, annual increase of new capacity has been more than 13000 MW, although it slowed down from 2010 to 2011.

China's practice shows that these policies work well for stimulating production capacity expansion, but not for the relationship between power generation and transmission as demonstrated by the large idle capacity. In statistics, the idle capacity is defined as the rated capacity of installed turbines that do not work within one year.[2] It differs from the curtailment of output due to the limitation in grid scheduling or the mismatch in electricity supply and demand. Usually, if and only if a turbine does not work for more than one year it is considered idle. For instance, the idle capacity in 2011 was 4936.7 MWs (see Table 3), which means that the rated capacity of installed non-working turbines was 4936.7 MWs. Similarly, China Electricity Council (CEC) reported that the capacity of turbines connected into grid is 45051.1 MWs [29], suggesting a cumulative idle capacity of 17313.1 MWs (=62364.2−45051.1) by the end of 2011 and equivalent to 27.76% of total capacity.

Statistical data (see Table 3) show that about 1/3 of China's newly installed turbines have been idle since 2008, a fact clearly at odds with the intention of the policies above; besides, the capacity growth rate is far higher than that of the government's plan. *ML-REDP* targeted a 5 million kilowatt capacity by 2010, and 30 million by 2020. The planned target was met 10 years ahead of schedule, well beyond Chinese Government expectations. Generally, dramatic growth relates to the behavior of single-faceted pursuit of production, which deviates from technical improvement and sustainable development, and also is contrary to the national policy's original intention. So, China needs a policy adjustment to reduce idle capacity and increase the proportion of wind power as total electricity supply.

3. The causes of high-speed expansion and low usage

3.1. Current policies stimulate power companies to pursue increased capacity regardless of quality

Due to the benchmark pricing system, wind power prices are fixed by the local wind energy area benchmark price, regardless of quality.[3] Therefore, when capacity is fully utilized, gross income is directly proportional to capacity, i.e. the greater the capacity the more income generated

$$R=\sum_{i=1}^{n} h_i p_{s,i} q_i, \quad i=1,2,\cdots; \quad \text{s.t. } h_i \geq 0 \tag{3}$$

where R is gross income, h_i is the output coefficient and q_i is power company capacity i.

Power company profit equals the rest of gross income minus cost

$$\Pi=\sum_{i=1}^{n} h_i p_{s,i} q_i-\sum_{i=1}^{n} c_i, \quad i=1,2,\cdots \tag{4}$$

where Π is profit, c_i is the total cost of power generation i.

A power company's goal is to maximize profit; therefore, requiring the following optimal equation:

$$Max\ \Pi=Max\left(\sum_{i=1}^{n} h_i p_{s,i} q_i-\sum_{i=1}^{n} c_i\right), \quad i=1,2,\cdots \tag{5}$$

Obviously, there are two ways to satisfy this Eq. (5): (i) to increase capacity or (ii) reduce cost. However, the preferential policies, determined primarily by the benchmark price, requiring purchase in full and based on scheduling priority, cut the

[2] By report, turbines often have to sit idle on average for 4 months before they get connected into the grid [7].

[3] Generally, quality of wind power hinges on the stability of output and frequency, voltage fluctuation, flickers, voltage asymmetry and harmonics, etc. [33].

connection between profit and wind power quality. As a result, profit depends completely on output. Technological improvement cannot increase output in a short time. Hence, the optimal strategy for power companies is to increase capacity and adopt low-cost technology to maximize profit. This means the following decision making is optimal

$$MaxQ = Max \sum_{i=1}^{n} q_i, \quad i = 1, 2, \cdots; \quad \text{s.t. } c_i \le q_i p_i, \ p_i \le p_{s,i} \tag{6}$$

where Q is the total capacity of a wind power developer, p_i is electricity price satisfying internal rate of return.

Eq. (6) implies that capacity determines wind power developers′ profits, meaning that expanding capacity as much as possible, regardless of generation quality, is developers best option, since China has not established wind power quality criteria. This is a typical Nash strategy [8]. Note that generation quality differs from wind resource quality (see footnote 3). Wind power quality depends on generation technologies and equipments. Advanced technologies and equipment can usually guarantee high quality wind power, but it is very expensive [7]. However, high quality wind power does not promise developers corresponding high returns under current Chinese wind power policies, which have no wind power quality requirements. This means using advanced technology and equipments merely increases costs. Therefore, developers seeking maximum production capacity are more willing to adopt relatively cheap technologies and equipment to achieve quantity of output regardless of output quality. In fact, wind power quality is often so poor that grid companies are unable to feed in [4,7,19,20]. This obvious external diseconomy deviates from the policy′s original intent, creating a moral hazard in term of economics, because using advanced technologies and equipment reduces rate of return and weakens investors′ competitiveness. However, those investors, who are not interested in technological innovation, but merely profit from projects, can complete projects easily, with low cheap capital input. This is called adverse selection in economic terms.

3.2. Existing policies discourage grid enterprises from improving wind power integration technology

Wind power quality has a crucial effect on the quantity of grid integration allowed. Generally, the higher its quality, the greater its grid integration is. Similarly, grid technology also plays an important role in connecting wind power. More advanced grid technology increases wind power feed in ability. Therefore, there are two basic ways to expand wind power integration: (i) raise wind power generation quality; and (ii) improve grid technology. The former depends on wind power company efforts, but they have no incentive to invest in the solutions, as we have argued in subsection 3.1, under existing policy. We show below that grid power companies are also unwilling to improve wind power connection technology.

According to the benchmark price policy, power grid company costs for wind power connection is

$$E_P = \sum_{i=1}^{n} p_{s,i} q_i \tag{7}$$

where E_P is the cost of purchasing electricity.

Eq. (7) shows that power grid companies pay a fixed price $p_{s,i}$ whether they improve grid technology or not. On one hand, the laws and rules concerning wind power do not require grid companies to connect wind power into grid when wind power cannot satisfy the technology requirement for grid connection. Therefore, rejecting low-quality wind power does not result in financial losses for grid companies. Some leading countries use the same practice. For example, in Spain, the system operator (SO) has the authority to curtail wind power generation if needed for system security [34]. On the other hand, to accommodate low-quality wind power, grid companies need huge investments to strengthen infrastructure and improve technology to manage wind power′s instability, on top of additional generators for peak hours. This increases grid company costs. Moreover, due to higher prices for wind power than traditional energy sources, wind power integration raises user costs, which in turn, leads to reduced electricity demand [14]. These factors will reduce grid company profits. This means that grid companies get no return from improving wind power connection technology, so they are not interested in it.

Given that technology remains unchanged, the allowable grid-connected wind power capacity will be limited to a relatively low level, otherwise the grid cannot work. Hence, any generation beyond the allowable capacity will be curtailed, even if wind power has network access priority. Chinese wind power grid infrastructure is very different from other leading countries, being rather weak with no capability to endure the low-quality wind power connection impact [20,29,34]. In particular, China′s geographic distribution of wind resources does not match well with power demand, since the most abundant high-quality wind resources (north east and north west provinces in particular) and large-scale installation areas are far away from electricity demand centers [10,12]. Therefore, a big gap exists between installed wind power capacity and grid transmission capability [8,29]. For these reasons, although wind power is no more than 2% of total electricity supply nationwide, it is too large-scale to feed into smaller local grids [29]. Statistical data show that the curtailment of wind power is rather severe [4].

3.3. The strategies of power and grid companies aggravate the imbalance between capacity and utilization

The fast growth of capacity requires corresponding grid integration ability. However, grid accommodation, which depends mainly on technology and infrastructure, develops more slowly, because existing policies discourage grid enterprises from improving wind power integration technology, including system control, dispatch and transmission, etc. As a result, the ability to accommodate wind power has fallen far behind wind power installation growth. Furthermore, low quality generation, resulting from generators′ single-faceted pursuit of output, disrupts the balance between generation capacity and integration capability. This aggravates the relative wind capacity surplus, observed as idle capacity. Statistical data imply that China′s idle wind power capacity constitutes a small relative surplus, because China′s percentage of wind power in terms of total electricity supply is rather low (see Table 3). By the end of 2011, wind power utilization accounted for less than 1.5% of China′s total electricity consumption, much lower than in other top five capacity countries (see Table 4, also [30]). However, large-scale wind farms are located mainly in the north and west of China, where grids are fairly weak and do not have enough capacity or technology to feed in the wind power. This results in large amount of idle installed turbines north and west and an inadequate supply of electricity in the south and east of China, the electricity demand centers [29].

To sum up, China′s current wind power policies have created a reverse incentive to generators and transmitters simultaneously, which may be called the dual reverse incentive. A feasible way to scale up the amount of grid-connected wind power, and improve the wind power development efficiency in China, is to increase policy incentive compatibility for both generators and transmitters.

4. Policy recommendations

The above analyses show that the combination of fixed price, scheduling priority and full acquisition have weakened power and grid company motivation to improve the technology necessary to guarantee wind power grid access. Therefore, appropriately adjusting existing policies to establish a suitable incentive for these companies to improve technology is the fundamental way to promote large scale wind power connection and reduce idle wind power capacity. In order to realize this target, we recommend the following measures:

4.1. Rationally distribute interests of wind power development among various participants

China needs to reform its wind power policies to rationally distribute wind power development interests among participants, including wind power farms, grid companies, and other generators such as thermal power stations and hydropower stations, which provide ancillary services. Although the fixed feed-in tariff, scheduling priority and full acquisition appear to be good ways to encourage wind farm construction investment individually, together they promote excessive wind farm installation regardless of output quality and discourage other participants, especially grid companies, from supporting market operation aspects, such as dispatch, schedule, peaking, etc., when they were packaged into an omnibus bill. Therefore, the wind power pricing system needs to be changed. The new pricing policy should remove the reverse motivation on wind farms and make wind power integration for grid companies and other participants more profitable. An alternative is to permit bargaining between grid companies and wind farms within the benchmark price rather than force grid companies to pay wind farms at a fixed price. Under such an arrangement, wind farms will pay attention to improving quality to receive a good price from grid companies and grid companies will have incentive to increase wind power feed-in for profit. At the same time, other participants can obtain interest from wind power access by providing corresponding services like balancing output, frequency modulation and peak-regulation, etc. This is similar to the Danish format, where grid connection costs are shared between wind farms and grid companies and the grid companies have the right to reject wind power connections if those connections make costs excessive [32].

We also recommend providing tax breaks and financial support to grid companies. As grid companies increase wind power accommodation, they should receive tax breaks and financial support in line with those power companies receive. An important step is to work out a specific program, including scope of application, measures and institutional system, etc. This will help grid companies reduce technological improvement costs so as to encourage them to address wind power idle capacity by increasing their connection to it.

4.2. Set up risk-sharing system

Wind power is weather dependent, making output not always reliable. As a kind of risk, wind power inconsistency heavily impacts grid function. For this reason, in Spain, wind farms are required to control output fluctuations within the scope of 20%, otherwise they pay for imbalances [34,35]. The UK, Netherlands and USA obligate wind farms to pay for wind-induced system imbalances, while in Germany and Denmark grid companies (TSO/DSOs) are solely responsible for system balance [35]. However, current Chinese policies lack clear regulations that guarantee wind power quality and system balance. Thus, neither developers nor grid companies take charge of resolving the conflicts between wind power output fluctuations and system balance. This prevents both companies from improving technologies [19]. Thus, large amounts of wind power are negated to keep network balance. This is one of the main reasons why grids cannot accept large wind capacity [4,19,20,29], making the clarification of how to control and share this risk a priority.

Risk-sharing system design should emphasize the coordination of incentives and enforcement. On one hand, it needs to make transmitters and generators comfortable enough to take certain risks; on the other, evading risk sharing must be strictly prohibited. China could learn from the example of countries like Spain, UK, Netherlands and the US (specifically, California), where wind power producers are responsible for system balance, or Denmark and Germany, where grid companies (TSO/DSOs) bear all responsibilities for it [35]. The first thing China needs to do is to designate a reasonable scope within which grid companies are obliged to manage system balance, like Denmark and Germany, and at what point power companies should be penalized, like in UK and Spain. Secondly, to increase risk sharing efficiency, integration bargaining between power and grid companies should be encouraged. For example, in California, wind power producers pay the system operator a forecasting fee. In turn, the system forecaster uses data from all wind power producers to establish a wind integration ratio minimum. This minimum ensures that power and grid companies participate fairly in improving technology and coordinating wind power use. Any imbalances falling outside the forecast are settled according to monthly net imbalances [35].

4.3. Stimulate wind farms to meet consumption fluctuation

China's existing policies cause wind farms to ignore market signals and blindly pursue high installation levels to maximize their profits. Most Chinese wind farm output increases during spring, winter and at night, and decrease during summer, autumn and during the day. Peak electric power demand periods usually occur during summer and daytime. As a result, reverse peaking is one of the natural properties of most wind farms in China [19]. Technology and infrastructure need to be improved to address this issue. However, both power and grid companies are reluctant to invest in technological and infrastructural improvement due to the imbalance between investment and revenue under current policies. Therefore, China needs to establish some supplementary measures aimed at encouraging wind farm developers to meet consumption fluctuation. The main supplementary measures are presented below.

First, China ought to establish a center for controlling its electricity schedule, such as in Spain where an efficient control system has been in place since 2006. The center monitors the grid schedule and balances consumption with wind farm output. Its main tasks include (i) publishing technological criteria, (ii) supervising and controlling grid operation and wind power output, and (iii) recording and fining parties that do not meet the required criteria. Under this process, wind farms have to improve their technology and respond appropriately to consumption signals. In this way, the conflict between grid schedule and wind power output will be directly relieved to some extent.

Second, wind farms should be required to forecast their output and inform grid companies. It is necessary to cap forecasted output deviation. For instance, deviation in Spain must not exceed 20% [35]. Once output deviation is more than the permitted limit, the wind farm pays fine to the grid company, and the fine increases with greater deviation. Up to now, most of China's wind farms have not been able to forecast their output. However, some provincial grids, such as Inner Mongolia, Jilin, etc., have installed wind power output forecasting systems. Therefore, encouraging wind farms to install power prediction systems is fully feasible.

This will promote coordination between wind power output and grid accommodation to a great extent.

Third, China needs to give aid to wind farms to increase output forecasting. This aid can be in the form of technical assistance, tax breaks and financial support. Wind power development in China started relatively late and wind power companies lack technology and capital. The rapid growth of China's wind power has resulted from scale expansion rather than technological progress. This is an important reason why wind power farms cannot match consumption and why, in part, reverse peaking is an issue. For this reason, China should lighten wind farms' financial burden of installing output prediction systems and provide necessary technological guidance and consulting.

5. Conclusions

China's policies have greatly enticed wind power developers to invest in the wind power industry and installation growth has been tremendous. However, these policies have crucial drawbacks, especially in incentive benefits distribution, risk sharing and response to consumption. Consequently, the interests of the players in wind power development, especially wind farms and grid companies, are in conflict. This hampers wind power penetration levels and results in large idle installations. Therefore, the crux of the matter is to make policies more balanced.

First, China needs to reform its wind power pricing system so as to eliminate unfair benefit distribution and promote coordination among Chinese wind power development participants. Second, risk-sharing mechanisms should be constructed as soon as possible, to specify and standardize measures so that all stakeholders are aware of and carry out required obligations, such as which party is responsible for system balance and how and when penalties are charged, etc. Third, an administrative system with economic incentives and mandatory regulations should encourage wind farms to meet grid connection requirements.

All in all, a feasible approach to China's wind power development goal is to pay attention to reasonable policy improvement and mechanism design rather than government intervention. This approach can guarantee idle capacity reduction, wind power development promotion, and ultimately environmental protection.

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